

## EXO-ELECTRON EMISSION FROM METALS

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In conjunction with the Bendix Corporation and, gratefully, with the support of the AFOSR, we are currently investigating the exo-electron emission behavior of metals. Since our primary objective is to try to obtain a much better basic understanding of the mechanism or mechanisms of exo-electron emission, we are adopting a rather basic approach to this problem which means that we are using essentially pure metals and, more importantly, the measurements are being carried out in very carefully-controlled gaseous environments. In particular, these include controlled partial pressures of various pure gases such as oxygen, water vapor, and carbon monoxide, as well as ultra high vacuum measurements.

The reason for taking pains to control the environment is because exo-electron emission is basically a surface phenomenon and it is extremely sensitive to the surface condition of the sample, both its chemical and physical nature. One of the reasons in my opinion, why so little of a definitive nature is known about exo-electron emission phenomenon is simply because not enough attention has been paid to environmental control in the past.

We are going to concentrate our attention particularly on titanium about which relatively little is known in order to avoid excessive duplication of work of a similar nature which is being carried out here at the Science Center and which is mostly being done on aluminum.

At the present time we have just assembled our apparatus and are checking it out. Specimens are being machined and, unfortunately, I don't have any actual data to report. I will try, however, to give you at least a brief description of some of the experiments that we plan to carry out and

what we hope to learn from them. In addition, I would like to acquaint you with some recently published work in this area which points to the possible potential of exo-electron emission as a tool for nondestructive evaluation of fatigue damage and for possibly locating the sites for potential fatigue failure.

It has been known for something over 70 years now that if you scratch the surface of a metal in air or mechanically abrade the surface or deform it in some manner, that the surface will emit electrons from the area which has been deformed. For a long time this phenomenon remained quite a mystery. It is also possible to stimulate emission of a similar nature from many other materials such as oxides, dielectrics, semiconductors, and even biological materials.

There is currently a great deal of interest in these phenomena, not only from a scientific standpoint, but also from a standpoint of possible applications. For example, a rather large scale effort is now in progress at the Health Physics Division at Oak Ridge in trying to develop exo-electron dosimeters, i.e., radiation dosimeters, based upon the use of thermally-stimulated exo-electron emission and, as you are probably aware, there have been and still are some rather strenuous attempts being made to try to develop a nondestructive testing technique for metals based on exo-electron emission. I think one of the major stumbling blocks at the moment in trying to do this is that really not much is known of a fundamental nature about this phenomenon.

We are planning to mechanically deform metals in controlled environments. We have built a mechanical straining device which is incorporated in our ultra high vacuum system. This is instrumented so that we can measure the load and the strain applied to the specimen, and we are going to study the emission as a function of the strain or deformation, investigate the effect of the environment as I have previously mentioned and investigate the effect of oxide thickness on the emission behavior. In most previous experiments that have been done, the only quantity that has been measured has been the total emission occurring or the emission yield. There are

many advantages to be gained in terms of trying to understand the basic phenomenon if, in addition to measuring just the total current one measures the energy distribution of the electrons which are emitted and, so, we have set up a rather simple retarding potential energy analyzer which we will use to determine the energy distribution of the emitted electrons. At the same time, we are measuring the change in surface potential or contact potential, so we can correlate the emission behavior with the change in work function of the surface. The measurements are rather difficult and time-consuming. We hope, however, that the results which we obtain will be of some value to people who are trying to develop a nondestructive testing technique based on the use of this phenomenon.

What the prospects might be are difficult to say at the moment, but I'd like to discuss with you some examples of attempts that have been made in this direction which do show some promise. First, some correlations have been established between the intensity of the emission and the degree of the plastic strain in a tensile experiment. The fact that such correlations exist, at least if the experiments are carried out in vacuum, indicates that the technique may have some potential.

I think the real value of exo-electron emissions as an NDE tool may lie in its imaging capability, that is, the possibility of being able to image defects, surface defects that may be present after fatigue. One of the first, easiest, and simplest demonstrations of this effect was given by Mellican and Bauer in about 1960. They took a single crystal of zinc and pulled it in tension. They then applied a photo-sensitive emulsion to the surface and let the crystal sit in the dark, stripped the emulsion and developed it.

They observed photographic darkening coming from the most highly deformed regions at the surface. This is obviously not a practical way to image surface defects. I am not aware of this simple photographic technique having been used for example on fatigue specimens, but it wouldn't surprise me if small surface cracks that developed as a result of fatigue could be imaged just by simple photographic methods.

A much more impressive demonstration of the potential of the exo-electron emission as an imaging device has been provided by Virman. He photo-stimulated the emission from aluminum with ultraviolet light using a very tightly-focused light spot that scanned the surface after the specimen was fatigued and detected the emission with a gas flow Geiger tube. With this technique, he was able to image fatigue cracks of the order of 100 mils in length. His images correlated favorably with optical micrographs at magnifications of about 200. The resolution that one can obtain with this scanning technique depends upon the size of the light spot that you use to scan with. That can easily be made as small as 15 or 20 microns, which means you should be able to detect cracks as small as one mil if the method is used properly.

Further work has been done by Baxter in obtaining emission correlations with strain. He deformed his specimens in bending, and the intensity-the emission intensity-was found to be nearly a linear function of the tensile strength. Interestingly enough, he found no emission from the compression side of the sample, and I do not understand this. He also found a correlation with fatigue deformation using a scanning technique. He found that he could detect emission from local regions on the surface of the specimen at less than a tenth of a percent of expected fatigue life and that the emission peaks increased in intensity with the number of cycles. Because of the good correlation he obtained, he concluded that under proper conditions it may be possible to utilize exo-electron emission for predicting fatigue life or locating the position on the surface of a sample where a fatigue crack might develop and ultimately cause failure. Our serious need at the moment is to develop some physical understanding of the origin of exo-electrons so that we may develop some confidence in it as an NDE tool.

Thank you.